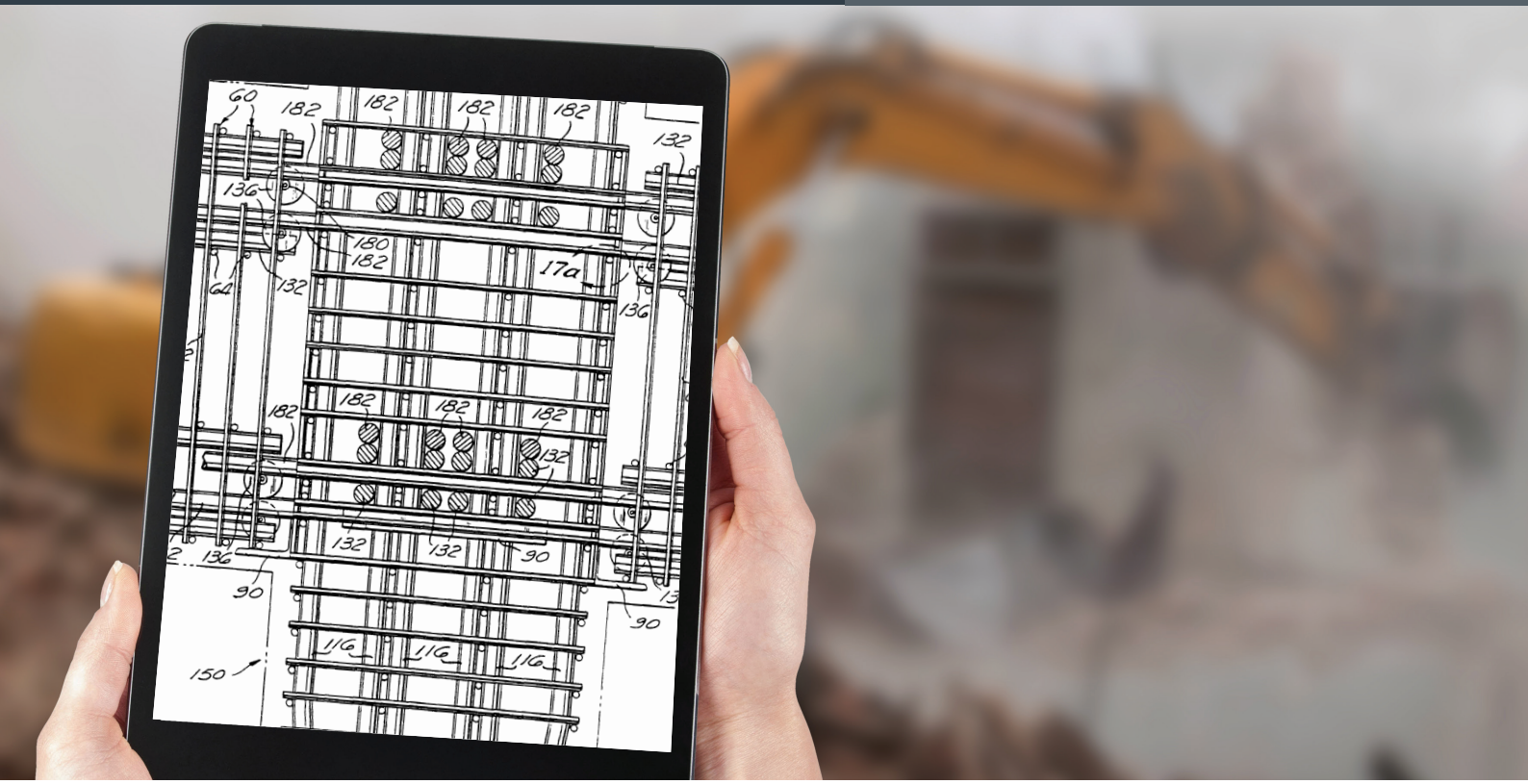
UNIVERSITY OF CAMBRIDGE

Transforming construction: impact case study

Benefits to industry: boosting productivity and improving quality; innovating construction; enhancing efficiency; securing competitive edge in international markets.



Taking a digital approach to the dimensional inspection of reinforcement cages to improve efficiency and boost productivity

The challenge to industry

Meeting UK government demand for lower-cost delivery of heavily reinforced infrastructure requires a step-change in the construction industry to improve productivity and efficiency.

Office for National Statistics (ONS) data suggests that productivity, measured by construction output per worker and construction output per hour, has shown very little improvement in the last 20 years. As the country prepares to leave the EU, there is pressing need for UK industry to address low levels of productivity and innovation to successfully compete for the commercial prospects that will offer growth and prosperity.

The construction sector lags behind other industries in its adoption of technology but the current digital abundance now offers construction a productivity opportunity through innovation.

It is vital for industry to invest in new technology – the economy of this country depends on having modern, fit-for-purpose infrastructure – and collaboration between industry and academia is key to this investment.

Improving methods

Reinforcement steelfixing, the act of placing and tying reinforcing bars to form a cage before pouring concrete, is a skilled and manually-intensive construction trade that has seen no improvement in productivity over many decades.

After steelfixing is completed, dimensional checks must be carried out by an engineer in a pre-pour inspection of the reinforcement cage to confirm compliance with national standards and to check project specific specifications and the reinforcement drawings for the particular pour. This process adds time to a project and can result in several rounds of re-work before acceptance. Structures using design for manufacture and assembly (DfMA) present additional challenge as coordination between in-situ and precast concrete requires extremely accurate placement of reinforcement.

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There is a clear productivity and quality benefit in replacing the current linear process of steelfixing and inspection with a parallel process of automated dimensional inspection as the steelfixing progresses.

The solution

The proposed digital approach brings together two emerging technologies – mixed (augmented) reality and automated as-built modelling. The intention of this research is to prove the feasibility of automated inspection and visualisation of reinforcement through mixed reality to catalyse industry use of this technology in its formative years. Industry adoption of this innovation will deliver time-saving as well as enhanced quality and productivity benefits.

Digital innovation

Finding a platform(s) and system(s) for capturing the data, processing and returning results that fit the needs of steelfixers and engineers while meeting the constraints of a construction site environment is key.

Sample point cloud data was collected using both simultaneous localisation and mapping (SLAM) algorithms and terrestrial laser scanning (TLS). Whilst a SLAM approach offers real-time data, it is not yet powerful enough to generate point clouds dense and accurate enough for reinforcement inspection. However, SLAM shows great potential via growth in mixed reality.

Algorithms were developed for the recognition of reinforcement from a point cloud, enabling the dimensional checks required by project specifications and national standards to be automatically conducted and recorded. It was crucial that these algorithms were computationally efficient, able to perform the recognition and inspection in seconds, to enable a real-time workflow. Traditional scan-vs-BIM techniques were not appropriate for this purpose as semantic understanding of reinforcement is required in order to inspect it (reinforcement may be geometrically dissimilar from a design BIM model but still meet specification and vice versa).

A registered point cloud and reinforcement BIM model are taken as inputs to the algorithms presented, with the BIM model providing:

- geometric information which is used in a novel way to aid reinforcement recognition
- textual and numeric parameters carried on the model objects used as the nominal basis for inspection.

The in/out of tolerance results on each rebar were displayed back to the user via mixed reality, which allows the accurate placement of reinforcement to be carried out 'in-process'. This digital approach provides information that reduces the risk of rework and creates as-built reinforcement models for remote inspection and a useful point of reference.

Mixed reality for inspection

A demonstrator app was created for the Microsoft Hololens (a self-contained, holographic computer, enabling the wearer to engage with digital content and visualise results), which superimposed the inspection results onto the as-built reinforcement cage in view. When viewing the model in this way, the Hololens was able to render the model with no noticeable dropping of frames or movement relative to the real world.

The effect of viewing the automatically inspected as-built model registered over the actual cage is very powerful, though the SLAM based data capture is not yet suitable and therefore a fully real-time 'end-to-end' process could not be demonstrated.

Future prospects

Mixed reality technology – capable of both augmentation and interaction with the real world – is in its first incarnation and the meshes generated are sparse, intended only for mapping large surfaces. Significant opportunity will arise when mixed reality technology has developed to the point that the point clouds generated have increased in density and accuracy such that data-capture, processing and feedback of results may be achieved in near real time on the device.

Impact and benefits to the construction industry

Taking a digital approach to the dimensional inspection of reinforcement cages will help to unlock productivity in construction that uses reinforcement steelfixing.

If dimensional inspection of the reinforcement cage is carried out in parallel with steelfixing itself, automatically inspecting the cage as it is assembled, the:

- quality will be improved making costly rework unnecessary
- productivity will be boosted due to time saving.

Automated reinforcement inspection could offer the UK construction industry a competitive advantage in international markets.

The Laing O'Rourke Centre for Construction Engineering and Technology, in the University of Cambridge Department of Engineering, was launched in 2011 with industry partner Laing O'Rourke to fulfil a shared vision of transforming the construction industry through innovation, education and technology. The Construction Engineering Masters (CEM) degree programme is designed to shape the next generation of industry leaders and undertake innovative research projects that deliver value to industry.

Case study

This case study is based upon a Laing O'Rourke Centre for Construction Engineering and Technology Construction Engineering Masters dissertation titled: Automated *Reinforcement Inspection: A Digital Methodology for Dimensional Inspection of Reinforcement Cages from Point Cloud Data with the Aid of an As-designed BIM Model* (2016). The research is by James Thorpe, Project Engineer, Laing O'Rourke.

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